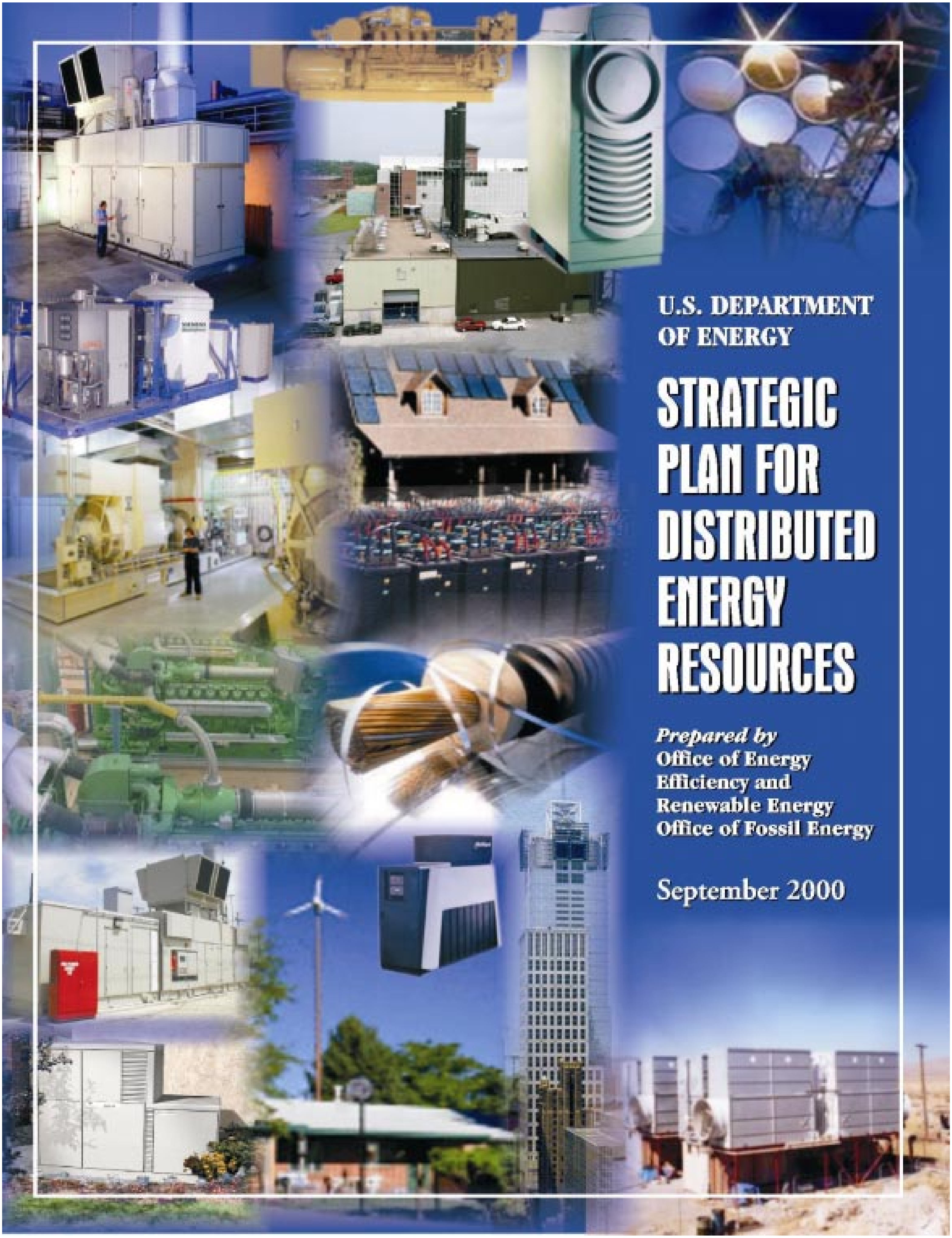

U.S. DEPARTMENT OF ENERGY

STRATEGIC PLAN FOR DISTRIBUTED ENERGY RESOURCES

Prepared by
Office of Energy Efficiency and Renewable Energy
Office of Fossil Energy

September 2000

ACRONYMS

AGA – American Gas Association
AGCC – American Gas Cooling Center
ASERTTI – Association of State Energy Research and Technology Transfer Institutes
BCHP – Buildings, Cooling, Heating and Power
CEC – California Energy Commission
CFCC – Continuous Fiber Ceramic Composites
CHP – Cooling, Heating, and Power (also known as combined heat and power, combined cooling, heating, and power, BCHP, cogeneration)
CNES – Comprehensive National Energy Strategy
DER – Distributed Energy Resources
DG – Distributed Generation
EEI – Edison Electric Institute
EPA – U.S. Environmental Protection Agency
EPRI – Electric Power Research Institute
ESCO – Energy Services Company
FEMP – Federal Energy Management Program
GTI – Gas Technology Institute
HHV – Higher Heating Value
MCFC – Molten Carbonate Fuel Cell
NASA – National Aeronautics and Space Administration
NASEO – National Association of State Energy Offices
NRECA – National Rural Electric Cooperative Association
NYSERDA – New York State Energy Research and Development Administration
R&D – Research and Development
RD&D – Research, Development and Demonstration
PCAST – President's Council of Advisors on Science and Technology
PEMFC – Proton Exchange Membrane Fuel Cell
PUC – Public Utility Commission
PV – Photovoltaic
SOFC – Solid Oxide Fuel Cell
SECA – Solid State Energy Conversion Alliance

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1. INTRODUCTION

Distributed energy resources can be distinguished from centralized energy resources in several respects. Distributed energy resources are small, modular, and come in sizes that range in capacity from kilowatts to megawatts. They comprise a portfolio of technologies, both supply- and demand-side, that can be located on-site or nearby the location where the energy is used. This provides the opportunity for greater local control and more efficient waste heat utilization to boost efficiency and lower emissions.

The portfolio of distributed energy resource technologies includes, for example, photovoltaic systems, fuel cells, natural gas engines, advanced turbines and microturbines, energy storage devices, thermally-activated cooling systems, humidity control equipment, wind turbines, demand management devices, concentrating solar power collectors, and geothermal energy systems. These technologies can be used to meet a variety of customer energy needs, including, for example, continuous power, backup power, remote power, cooling-heating-and-power, and peak shaving. They can be installed directly on the customer's premise or located nearby in district energy systems, power parks, and minigrids.

For the past eighteen months, the Office of the Under Secretary of Energy has been conducting a comprehensive review of the research and development (R&D) portfolio of the U.S. Department of Energy. This review has entailed developing – for the first time – a comprehensive description of all the Department's R&D activities in one coherent, strategic framework.[1] Analysis of the Department's energy R&D portfolio has revealed several areas in need of greater focus and emphasis to address critical unmet needs. One of those areas is distributed energy resources. Related efforts include major new initiatives in energy grid reliability, natural gas technologies, and bioenergy and biobased products.

The energy R&D partners of the U.S. Department of Energy – manufacturers, businesses, utilities, laboratories, universities, state agencies, and public interest groups – have acknowledged that there is an expanding role for these smaller scale, cleaner, and more fuel efficient energy generation systems in meeting the world's needs for energy. Over the past several years, the Department has engaged in discussions with hundreds of stakeholders as part of an extensive series of visioning, roadmapping, and multi-year planning processes. In these discussions, many stakeholders have commented on the importance of the federal government in the development and deployment of distributed energy resources. For example, the Natural Gas/Renewable Energy Alliance was recently formed by more than twenty leading organizations from the renewable energy and natural gas industries for the purpose of defining a common set of actions to promote the use of clean and distributed energy solutions.

The purpose of this document is to outline the vision, mission, goals, and strategies of a new crosscutting effort to strengthen the integration of the research, development, demonstration, and deployment programs in the Department that address distributed energy resources. These programs include efforts that currently reside in the Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy. This document contains descriptions of the existing programs and offers ideas for several new initiatives. This document also includes a discussion of the market drivers and issues, program management and coordination, potential public benefits, and a glossary of terms.

Additional information on the U.S. Department of Energy's activities in distributed energy resources and related technologies can be found on the Internet at www.eren.doe.gov/der and www.netl.doe.gov.

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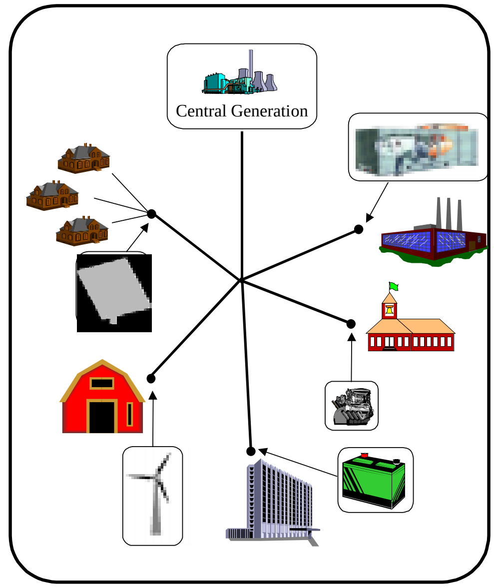
[1] U.S. Department of Energy, *DOE R&D Portfolio Overview 1999-2001*, February 2000

2. Overview



Distributed Energy Resources

Vision 2020

The United States will have the cleanest and most efficient and reliable energy system in the world by maximizing the use of affordable distributed energy resources.

Over the next two decades, industrial, commercial, institutional, and residential customers will be able to choose from a diverse array of ultra-high efficiency, ultra-low emission, fuel-flexible, and cost-competitive distributed energy resource products and services. These will be easily interconnected into the nation's infrastructure for electricity, natural gas, and renewable energy resources and operated in an optimized manner to maximize value to users and energy suppliers while protecting the environment.

Mission

To lead a national effort to:

- Develop the "next generation" of clean, efficient, reliable, and affordable distributed energy technologies;
- Document the energy, economic, and environmental benefits of the expanded use of distributed energy resources and disseminate the findings widely; and
- Implement deployment strategies, including national and international standards, that address infrastructure, energy delivery, institutional, and regulatory needs.

Goals

- The *long-term* goal for 2020 is to make the nation's energy generation and delivery system the cleanest and most efficient, reliable, and affordable in the world by maximizing the use of cost-efficient distributed energy resources.
- The *mid-term* goal for 2010 is to reduce the costs and emissions and increase the efficiency and reliability of a suite of distributed energy technologies to achieve 20 percent of new electric capacity additions in the U.S.[2]
- The *near-term* goals for 2005 are to:
  - Develop "next generation" distributed energy technologies, and
  - Address the institutional and regulatory barriers that interfere with siting, permitting, and interconnecting distributed energy resources coming on-line prior to 2005.

[2] According to preliminary analysis based on data from the Energy Information Administration, there were approximately 53 GW of distributed energy resources installed in the U.S in 1998. This includes facilities up to 50 MW in size. (However, most of the installations are smaller than this.) The goal of achieving 20 percent of capacity additions means adding approximately 26.5 GW of new distributed energy resource capacity by 2010. This amount represents an increase of approximately 4 percent per year.

STRATEGIES

- Direct and coordinate a diverse portfolio of research, development, and demonstration (RD&D) investments in distributed natural gas technologies, including:

  - Advanced turbines and microturbines
  - Cooling, heating and power (CHP) systems
  - Fuel cell systems
  - Hybrid systems (fuel cell/combustion turbine and fossil/renewable systems)
  - Natural gas engines

- Conduct supporting RD&D in enabling technologies, including:

  - Combustion systems
  - Fuel processing
  - Hydrogen energy systems
  - Materials and manufacturing
  - Power electronics
  - Sensors and controls

- Direct and coordinate a diverse portfolio of RD&D in energy generation and delivery systems architecture for distributed energy resources, including:

  - District energy
  - Energy storage
  - Grid interconnection
  - Modeling and simulation tools
  - Power parks and mini grids
  - Superconducting materials for electric systems
  - Transmission and distribution

- Coordinate activities with RD&D in renewable energy development, including:

  - Concentrating solar power and solar buildings systems
  - Geothermal
  - Photovoltaic systems
  - Wind energy systems

- Establish collaborative technology transfer partnerships with industry, state agencies, universities, and national laboratories, including:

  - Multi-year plans, industry visions, and technology roadmaps
  - Cost shared research, development, and demonstration projects
  - Cost shared technology transfer activities

- Conduct systems integration, implementation, and outreach activities aimed at addressing infrastructure, institutional, and regulatory needs, including:

- Building codes and standards
- Environmental permitting and siting
- Federal Energy Management Program
- International President's Council of Advisors on Science and Technology (PCAST)
- Standardized interconnection protocols
- State initiatives
- Tax provisions
- Utility restructuring

INITIATIVES

To strengthen the distributed energy resources activities of the Department, several new initiatives have been identified. These initiatives, which are listed below, are discussed in more detail later in this document.

- Biofuel Flexibility
- Fossil/Renewable Hybrids
- Solid State Energy Conversion Alliance (SECA) for Fuel Cells
- Systems Integration, Testing, and Case Studies
- System Architectures
- Zero Energy Buildings

LINKAGES TO THE COMPREHENSIVE NATIONAL ENERGY STRATEGY (CNES)[3]

This program addresses all five of the CNES strategic goals:

- Improve the efficiency of the energy system.
- Ensure against energy disruptions.
- Promote energy production and use in ways that respect health and environmental values.
- Expand future energy choices.
- Cooperate internationally on global issues.

[3] This plan contributes to and is supported by several other recent R&D planning and analysis documents published by the U.S. Department of Energy. These include: *DOE Research and Development Portfolio – Energy Resources,* Office of the Under Secretary of Energy, April 2000; *Office of Energy Efficiency and Renewable Energy Strategic Plan,* March 2000, DOE/GO-102000-0956; *Office of Power Technologies Strategic Plan,* July 2000. This plan also responds to recommendations contained in *Renewable Power Pathways,* an assessment published by the National Research Council of the National Academy of Sciences in April 2000.

3. Situation Analysis: Drivers, Trends, and Issues

Drivers

Global economic and population growth. Technological advances. Power quality and reliability problems. Environmental quality. Utility restructuring. These are the major driving forces underlying the need, and the opportunity, for re-engineering the nation's energy generation and delivery systems in the new millennium.

For example, as the economies of countries in both the industrialized and developing worlds expand, so too is the global demand for energy. As a result, global sales of energy generation equipment are growing, including sales of distributed energy systems such as photovoltaic cells, wind turbines, reciprocating engines, and gas turbines. At the same time, technological advances in computers, information, and telecommunications systems have reshaped commerce on a global scale, thus affecting the value of energy, particularly electricity, in accomplishing business activities. In fact, in part due to the rising importance of e-commerce, power quality and reliability are now more important than ever to ensure the smooth operation of "mission critical" business and manufacturing functions.

In addition, with rising education levels and increased global communications, the general public is more aware of environmental problems and potential health and safety hazards. As a result, public concerns about the environment, public health, and safety are increasingly being reflected in laws and regulations. One outcome is more stringent environmental requirements for businesses and industry. For example, implementation of the Clean Air Act in the U.S. is requiring jurisdictions in non-attainment areas to undertake a variety of measures to reduce emissions from power plants.

At the same time, the restructuring of electricity and natural gas markets is on the rise in states across the nation and in countries around the world. This has led to strong competitive pressures on utility companies and is now enabling many industrial, commercial, residential, institutional, and governmental customers to choose - for the first time - their utility providers, method of delivery, and attendant energy services.

As a result of these and other driving forces:

- Worldwide demand for electricity is expected to double in the next twenty years.
- The efficiency of small, modular systems has begun to exceed the efficiency and environmental performance of central station power plants in certain applications.
- Regional and global environmental concerns have made efficiency and environmental performance an important consideration.
- Industrial and commercial customers have grown increasingly concerned about the reliability and quality of grid-connected electric power.

Trends

Domestically, the demand for electricity is projected to increase more than 1 trillion kilowatt-hours over the next twenty years, which will require the addition of approximately 300 gigawatts of electric capacity by 2020.[4] Distributed energy resources will compete for a share of this market. Achieving the goal of this program (capturing 20 percent of capacity additions by 2010) will mean a substantial increase in the use of distributed energy resources and substantial public benefits in terms of more energy choices, lower emissions, greater flexibility and control, higher reliability, and lower costs.

Forecasts show the demand for electricity increasing by almost 9 trillion kilowatt-hours by 2020 in countries outside of the U.S., with much of this growth occurring in Asia and Central and South America in areas that have yet to install nationwide power grids.[5] This represents a tremendous opportunity for distributed energy resources in remote power applications.

International markets have become attractive but difficult opportunities for U.S. manufacturers and power project developers. The potential is large but the competition with foreign suppliers is intense. Since the end of the Cold War, countries that were once resistant to foreign investment have opened their markets to companies for construction and ownership of power generation and transmission and distribution facilities. The magnitude of this international market represents a substantial business opportunity for U.S. manufacturers and project developers of distributed energy resources. Federal investments in technology development through this program can boost manufacturers' international competitiveness, which in turn could lead to an increase in sales and high-paying jobs for U.S. workers.

ISSUES

One of the factors favoring the expanded use of distributed energy resources is the rising concern about the possibility of blackouts, brownouts, power supply constraints, and electricity price spikes in certain regions of the U.S. In fact, according to the North American Electric Reliability Council, expanded competition in wholesale power markets, along with mounting pressures to keep costs low, have been contributing factors in the use of lower reserve capacity margins in the regional power systems today than in the past. This situation increases the likelihood of power outages and reductions in power quality.

To address these concerns, the U.S. Department of Energy has held ten *Electricity Reliability Summits* in cities from coast-to-coast since April 2000. These summits have brought together federal, state, and local government officials, business leaders, utility executives, consumers, and environmental and labor groups to discuss ways to enhance the reliability of the Nation's power system. An investigation of several power system disturbances that occurred in several parts of the country was recently published.[6] The report found that the necessary operating practices, regulatory policies, and technological tools for assuring an acceptable level of reliability in the U.S. under restructured competitive markets are not yet in

California's Power Problems – Summer 2000

The power supply constraints that hit California this summer caused price spikes, rolling blackouts, and an outpouring of consumer complaints. Due to the booming California economy, electricity demand is soaring, particularly in those parts of the state where the growth in e-commerce is strongest. In some areas, electricity bills more than doubled or even tripled for some customers, compared to the same period a year earlier. Several "Stage 2 Emergencies" were declared on the days when spinning reserve margins fell below 5%, which led to power supply disruptions for some interruptible customers. In at least one instance a "Stage 3 Emergency" was narrowly averted when spinning reserves dipped dangerously close to the 1.5% trigger point. Calls for re-regulation of California's electricity market are on the rise as consumer advocates seek to avoid a repeat of this summer's power problems.

[4] *Annual Energy Outlook 2000 – With Projections to 2020* DOE/EIA-0383 December 1999
[5] *International Energy Outlook 1999 – With Projections to 2020* DOE/EIA-0484 March 1999
[6] U.S. Department of Energy *Report of the U.S. Department of Energy's Power Outage Study Team – Findings and Recommendations to Enhance Reliability from the Summer of 1999* March 2000

place.

Not surprisingly, concern about the reliability of the electric power system in the U.S. is escalating. A recent one-day power outage in the San Francisco Bay Area is reported to have cost manufacturers in Silicon Valley over $75 million in lost production. During a recent heat wave, the California Independent System Operator spent over $200 million to obtain emergency power to stabilize the system.[7]

With the increased use of sensitive electronic components, the need for reliable, high-quality power supplies is paramount for many businesses. The cost of power outages or poor quality power can be ruinous to companies that have continuous processing and pinpoint-quality specifications. For example, Connecticut-based American Home Products (AHP) has their own power plant that provides electricity and thermal energy to manufacture pharmaceutical products. The Pearl River Plant saves AHP millions of dollars from lost production due to utility outages.[8] In June 1998, the Midwest saw price spikes jump to $10,000/MWh from an average of $30/MWh. Almost two years earlier, California experienced widespread blackouts that cost over $1 billion in August alone.[9]

Table 1 illustrates in economic terms the problems unreliable power can create for businesses. Some companies have begun to address these problems by installing on-site power generation components such as gas turbines, gas engines, and phosphoric acid fuel cells.

Table 1. Selected Outage Costs

INDUSTRY	AVERAGE COST OF DOWNTIME	SOURCE
Cellular Communications	$41,000 per hour	Teleconnect Magazine
Telephone Ticket Sales	$72,000 per hour	Contingency Planning Research-1996
Airline Reservations	$90,000 per hour	Contingency Planning Research-1996
Credit Card Operations	$2,580,000 per hour	Contingency Planning Operations-1996
Brokerage Operations	$6,480,000 per hour	Contingency Planning Operations-1996

Another issue affecting the development of distributed energy resources is the difficulty of siting and permitting on-site, grid-connected facilities. In fact, project developers often face several regulatory and institutional barriers. For example, the existing regulatory framework for energy generation, delivery, and use favors incumbent suppliers. In addition, environmental siting and permitting requirements differ from state-to-state. While output-based emissions standards, pre-certification of certain types of systems, and other forms of environmental regulations could help some distributed energy projects, adoption of these measures is moving very slowly, and most states want further analysis before taking action.

Effectively addressing these barriers requires a comprehensive program strategy. Siting difficulties, along with a lack of uniform interconnection standards across utility service territories, typically leads to costly delays in project schedules. Despite all of the efforts to increase competition in electricity and natural gas markets around the world, fundamental resistance to change remains, as evidenced by continuing regulatory and institutional barriers.

[7] *Wall Street Journal*, June 26, 2000
[8] *Presentation by Al Forte to The CHP Summit* U.S. DOE December 1998
[9] Stahlkopf, Karl, "Meeting the Challenge of Power Delivery Reliability," *Power Economics*, June 30, 2000

A recent report documents 65 case studies of barriers to the installation of distributed energy systems.[10] In the report, 25 percent of the cases experienced interconnection delays of greater than four months. This study concludes that the problems encountered by distributed resource developers stem largely from:

- A lack of national consensus on technical standards for interconnecting distributed systems with the utility grid,
- Lengthy and costly approval processes that make many smaller projects uneconomic, and
- A lack of familiarity by utility companies in addressing customer-generator interconnection requests.

[10] National Renewable Energy Laboratory, *Making Connections – Case Studies of Interconnection Barriers and Their Impact on Distributed Power Projects* NREL/SR-200-28053 May 2000

4. Program Management and Federal Role

A. Program Management

The Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy will jointly manage this program. The Office of Policy and the Energy Information Administration will provide assistance as needed. The Department's internal R&D Council will also provide assistance in the management and implementation of programs. The program managers responsible for the technology development efforts described in this plan will report on the status of their distributed energy resources activities to the R&D Council on a regular basis.

Interested government sponsoring agencies (e.g., the U.S. Environmental Protection Agency, the Department of Defense, and the National Institutes of Standards and Technology) will be invited to participate in the program. An inter-agency working group will be established to identify and coordinate joint activities across the federal government. The various agencies that participate in the working group will be asked to communicate information about program activities and milestones. This information will be used to provide input into the technical direction of this program and its priorities. In addition, annual program reviews and periodic vision and roadmap sessions will be used to obtain inputs from industrial partners and other stakeholder organizations.

A number of other organizations will be involved in the implementation and coordination of the program. For example, the national laboratories will play a key role in the research and development portion of the program along with universities and private research and development organizations.

State government agencies will also be invited to play a role. For example, the National Association of State Energy Officials (NASEO), as well as representatives from several individual state energy offices, have identified distributed energy resources as a top priority target for development. The California Energy Commission (CEC) and the New York State Energy Research and Development Administration (NYSERDA) have distributed energy programs underway and are interested in further collaboration with the U.S. Department of Energy. The Association of State Energy Research and Technology Transfer Institutes (ASERTTI) also has an interest in distributed energy resources. NASEO, ASERTTI, NYSERDA, and the CEC have signed memoranda of understanding with the Department to conduct a variety of collaborative RD&D activities.

Electric and gas utilities' interest in distributed energy resources is growing. The Electric Power Research Institute (EPRI) is engaged in a variety of distributed energy resources demonstration projects. EPRI also has a memorandum of understanding with the Department and participates in yearly program review meetings to track progress on collaborative activities. The National Rural Electric Cooperative Association (NRECA) is pursuing several distributed energy projects with the Department and has expressed interest in expanding the level of joint activities. The Edison Electric Institute (EEI) is monitoring market development in distributed energy resources and has expressed interest in working more closely with the Department on these matters.

The natural gas industry is working with the Department on the development of several distributed energy technologies, particularly in the areas of combustion, advanced turbines and microturbines, reciprocating engines, and cooling, heating, and power systems for buildings and industry. Involved organizations include the American Gas Association (AGA), Gas Technology Institute (GTI, which is the organization that resulted from the recent merger of the Gas Research Institute and the Institute of Gas Technologies), the American Gas Cooling Center (AGCC), and the Buildings Cooling, Heating and Power (BCHP) Initiative.

Coordination and management of program activities will be accomplished in a collaborative manner with all program participants and stakeholders. This is shown in Figure 2 below.

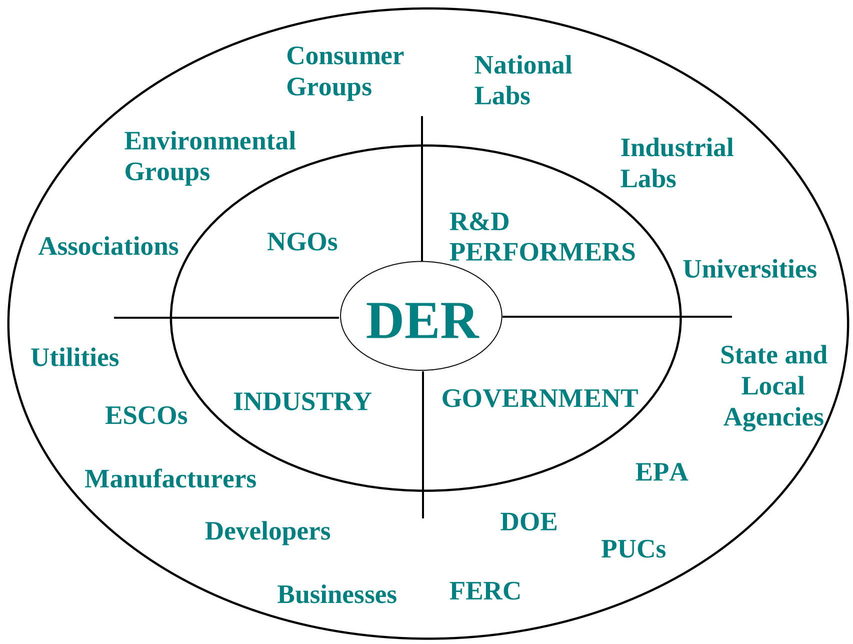


Figure 2. Program Coordination and Collaboration

B. Federal Role

The role of the federal government in the development and deployment of distributed energy resources is twofold:

1. Continue to support RD&D programs to raise the efficiency and performance, and lower the cost and emissions, of advanced distributed energy technologies so that a broader range of clean energy choices is available to all consumers; and
2. Address technical, regulatory, and institutional barriers and enable distributed energy resources to compete on an equal and consistent basis with other technologies to supply energy and ancillary services in competitive electricity and natural gas markets.

Decades of public and private investments in research and development have recently begun to yield major improvements in the economic, operational, and environmental performance of small, modular, renewable and natural gas-fired energy generation options. The U.S. Department of Energy has been the most significant and consistent sponsor of this research and development. The emerging suite of cleaner and more efficient, affordable, and reliable distributed energy resources is in the early stages of commercial development. Developers, energy service companies, independent power producers, and utility companies have just begun to offer these technologies to customers. More work needs to be done to improve the environmental performance and reduce the costs of these systems in order to ensure that they reach their full potential in the marketplace.

Pressure for enhanced environmental performance is mounting. In many regions of the U.S., there is near zero tolerance for additional emissions as areas strive to comply with existing clean air regulations. Public policies, reflecting rising concerns about pollutant emissions and greenhouse gases, are being designed to favor capacity additions that use high efficiency technologies and clean fuels. Continued federal support of energy R&D in advanced distributed energy resources is paramount if clean air goals are to be achieved.

The energy security of the nation is stronger when the economy relies on a variety of energy sources, and is not overly dependent on any single fuel. The federal government plays an important role in the nation's energy security. From the standpoint of the nation's entire portfolio of power generation technologies and fuels, distributed energy resources provide an opportunity for expanded fuel diversity since they operate on a suite of fuel forms. This suite of fuels includes: 1) solar power, 2) wind, 3) natural gas, 4) propane, and 5) fuel gas derived from a variety of hydrocarbon sources including coal, biomass, and off-gases and wastes from industrial processes, municipalities, and the forestry and agricultural sectors.

Ensuring competitive and efficient market operations in interstate commerce is an important function of the federal government. As interstate electricity and natural gas markets open up to competition, concerns are rising about the level of industrial concentration among electricity suppliers and the potential for market power abuses. A recent study published by the Department outlines several areas of concern.[11] Increased use of distributed energy resources can boost the level of supply, increase the number of suppliers, and increase the number of ways in which customers can gain access to the electricity they need.

The potential benefits of a federal program that addresses distributed energy resources to customers, suppliers, and the nation as a whole are discussed Section 6 of this report.

[11] U.S. Department of Energy, *Horizontal Market Power in Restructured Electricity Markets,* DOE/PO-0060 March 2000

5. PROGRAM ACTIVITIES

Through this program, the U.S. Department of Energy aims to strengthen national capabilities in distributed energy resources and provide support to a growing industry of manufacturers, energy service providers, project developers, federal and state policy makers, public and environmental interest groups, and consumers through:

- Research, development, and demonstration to optimize the cost and performance and accelerate the readiness of a portfolio of advanced renewable and gas-fueled distributed energy resources for both domestic and international markets;
- Policy analysis to address the regulatory and institutional barriers to the widespread deployment of distributed energy resources and to determine cost-effective solutions; and
- Partnerships with industry, state and local governments, national laboratories, and universities.

Obtaining guidance and technical input from the key stakeholder organizations is paramount to the overall success of the program. As a result, the Department will work closely with other federal agencies, state government agencies, utility companies, technology suppliers, industrial research organizations, universities, national laboratories, power producers, energy service companies, and end users. Representatives from these and other organizations will be invited to participate in program reviews, conferences and workshops, vision and roadmap processes, and multi-year planning exercises. The major areas of activity are shown below in Figure 1.

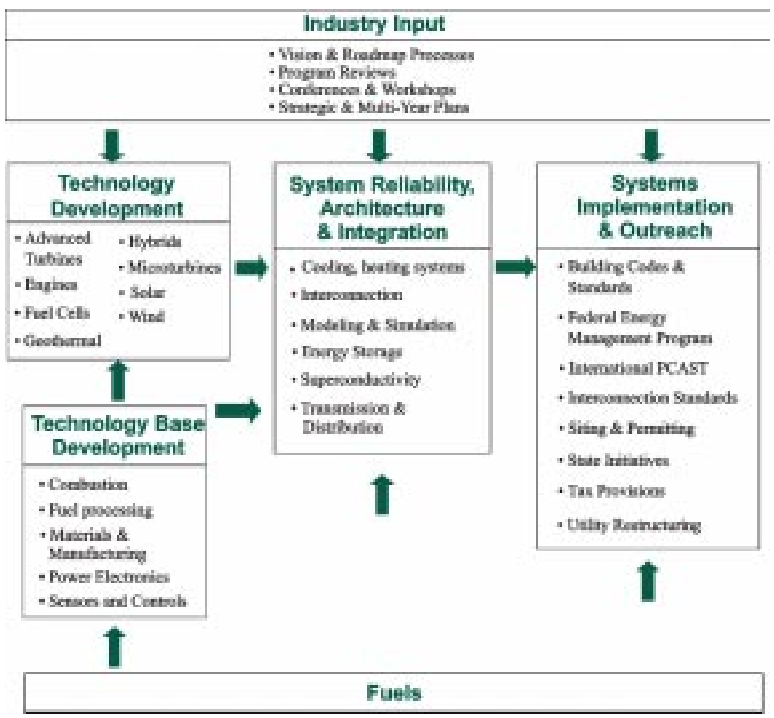


Figure 1. Key Elements of the DER Program

The activities outlined in Figure 1 are currently underway in Department offices and national laboratories. These activities, which are briefly discussed below, include: 1) support for cost- and risk-sharing technology development; 2) workshops, conferences and other forums for the discussion of issues and program content; 3) website development and publications to ensure that stakeholders and others have access to needed technical information; and 4) partnerships with critical agencies and organizations to support program goals. Several ideas for new initiatives to augment current activities are also presented.

A. Technology Development

Advanced Industrial Turbines and Microturbines. Combustion turbines are a class of electricity generation devices that produce high-temperature, high-pressure gas to induce shaft rotation by impingement of the gas on a series of specially designed blades. Many turbines also use a heat exchanger called a recuperator to impart turbine exhaust heat into the combustor's air/fuel mixture. Simple cycle efficiencies (i.e., without external use of exhaust heat) range from 21 to 40 percent. Turbines produce high quality heat that can be used to generate steam for combined cycle or combined heat and power applications, significantly enhancing efficiency. Maintenance costs per unit of power output for combustion turbines are among the lowest of all power generating technologies.

Microturbines

A key effort has been to enhance the performance of gas turbines for industrial applications in the size range of 20 megawatts or less. Current industrial scale simple cycle machines have efficiencies around 30 percent. The goal for advanced industrial turbines is to improve on that efficiency by 15 percent. Additional objectives are: 1) a 10 percent reduction in the cost of electricity, 2) enhanced fuel flexibility, 3) less than 10 ppm nitrogen oxides and 25 ppm carbon monoxide without post-combustion controls, and 4) reliability, availability, maintainability, and durability equal to or better than current systems.

Another key effort is the development of next generation turbine systems for near term distributed power markets and long term central power applications. One goal of this effort is to develop and test advanced designs at the sub-scale level. Concepts include turbo-machinery derived from ramjet technology and a gas generator/steam turbine power system that is currently being used to drive fuel pumps in the NASA space shuttles.

Microturbines are small combustion turbines with outputs of 25 kW to 1,000 kW. Microturbines evolved from automotive and truck turbochargers, auxiliary power units for airplanes, and small jet engines used on pilotless military aircraft. By using recuperators, existing microturbine systems are capable of efficiencies in the 25-30 percent range.

Microturbine systems are currently undergoing testing in commercial sector applications. The Department has initiated an Advanced Microturbine Systems Program with the goal of producing the "next generation" system that will be cleaner and more efficient, affordable, and reliable than the existing products. This program involves several activities including: development of concepts and designs, development of advanced components and subsystems and system integration, and field-testing and demonstrations. The performance targets of the Advanced Microturbine Systems Program are to: 1) increase fuel-to-electricity conversion efficiency to at least 40 percent; 2) achieve NO_x emissions of less than 7 parts per million; 3) achieve durability targets of 11,000 hours of operation between major overhauls with a service life of at least 45,000 hours; and 4) achieve system costs lower than $500 per kilowatt and costs of electric power production that are competitive with alternatives for market applications.

Concentrating Solar Power and Solar Buildings Systems. Concentrating solar power systems use sun-tracking mirrors to reflect and concentrate sunlight unto a receiver where it is converted to high temperature thermal energy. The high temperature heat is then used to drive an engine or electric generator. Rooftop systems convert sunlight to hot water for residential and commercial uses.

The 2004 goal for concentrating solar power collectors is to reduce the cost of dispatchable systems from $0.12 per kilowatt-hour to less than $0.08 per kilowatt-hour. The goal for solar systems in buildings is to reduce the cost of solar water and space heating from $0.08 per kilowatt-hour to $0.04 per kilowatt-hour. These goals will be accomplished by continuing efforts in dish/engine systems including: field validations and remote power installations; solar trough components research; advanced systems for concentrators, materials, and receivers; and development of hybrid solar lighting systems that use fiber optics. The effective integration of solar technologies into the design of buildings is a major R&D challenge. Solar technologies can be more fully utilized in roofing, walls, windows, and other building components and subsystems than they typically are today.

Cooling, Heating, and Power (CHP). Cooling, heating, and power (CHP), or cogeneration, involves capturing waste heat from power production and putting it to some useful purpose at the customer site. The development of CHP systems has the potential for over 90 percent fuel utilization efficiency in industrial, commercial, and residential applications. CHP combines a "prime mover" system such as combustion turbines, reciprocating engines, or fuel cells with waste heat recovery equipment for the production of hot water, steam, cooling, mechanical energy, and regeneration of desiccants for humidity control in buildings.

Large-scale CHP systems are heavily used in the pulp and paper, chemical manufacturing, and petroleum refining industries. However, significant opportunities in these industries remain. The emergence of smaller scale power generation systems has opened new opportunities for CHP in other manufacturing industries and commercial buildings. In certain settings, waste heat can be used for hot water, chilled water, and/or steam that can be circulated through pipes to several thermal energy users. These district energy systems are tremendously cost effective.

Technology development is planned in the area of cooling, heating, and power systems for buildings. This includes research and development in a variety of natural gas-fired building systems such as absorption chillers and desiccant dehumidification systems. These systems can be integrated with electricity generation equipment such as advanced turbines and microturbines, fuel cells, and natural gas engines. These efforts are aimed at making CHP systems a competitive energy choice in commercial and government buildings. Efforts will focus on systems integration technologies for electric power, space heating and cooling, humidity controls, and indoor air quality.

Drugstore Demonstrates Microturbines with CHP

With the help of the local utility, national drugstore chain Walgreens has installed a 28-kilowatt Capstone Microturbine at its Chesterton, Indiana store. Since August 1999, the natural gas-fired unit has provided 33% of the building's electric, heating, air conditioning and hot water needs. The system uses an absorption chiller and heating system and desiccant dehumidification system powered by exhaust heat from the microturbine. Power outages can be costly for establishments like Walgreens; this new system, which operates around the clock, could maintain power for the entire store during an outage. Under the terms of the demonstration, local utility NiSource paid for installation. Walgreens is responsible for the fuel. Yvette Venable, a representative from the Chesterton store said, "We have not experienced any problems with the system. It has been reliable and we have been very satisfied with its performance."

Fuel Cells. Power is produced in fuel cells electrochemically by passing a hydrogen-rich fuel over an anode and air over a cathode and separating the two by an electrolyte. In producing electricity with fuel cells, the only by-products are heat, water and carbon dioxide. However, hydrogen fuel is produced by subjecting hydrocarbon resources to steam under pressure (called reforming or gasification), a process that often requires combustion and consequently environmental emissions.

Phosphoric acid fuel cells (PAFCs) are currently in the market entry phase. More than two hundred PAFC units, most in the size range of 200kW, have been manufactured for sale to customers worldwide. Molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC) units are undergoing full-scale demonstration, and proton exchange membrane fuel cell (PEM) units are in early development and testing.

Phosphoric Acid Fuel Cell

To create a complete package, the fuel cells are integrated with an inverter to convert the direct current to an alternating current. The direct electrochemical reaction in lieu of moving parts to produce electricity has inherent efficiency advantages. PAFCs are realizing efficiencies over 40 percent, and the MCFCs and SOFCs will reach 60 percent efficiency. When used in combined heat and power applications, thermal efficiency greater than 85 percent is possible, particularly with the high-temperature MCFC and SOFC systems. The absence of moving parts results in very low noise levels. The stacking of cells to obtain a usable voltage and power output allows fuel cells to be built to match specific power needs, and the modularity makes capital cost relatively insensitive to scale.

Fuel cells are being developed for stationary power generating applications in partnership with the private sector. This effort is the largest single source of funding for fuel cell research and development in the U.S. This fuel cell program has near-term achievable cost and performance goals that emphasize efficiency, reliability, and longevity. Over the past several years, the primary focus of the program has been on the development of advanced high-temperature fuel cells by 2003. These fuel cells have higher efficiencies and lower capital costs than existing units, and are potentially suitable for near-term market applications. High-temperature fuel cell types include MCFCs and SOFCs. The goal for 2003 is to commercially introduce high-temperature natural gas-fueled MCFC and SOFC at $1,000-$1,500 per kilowatt that are capable of 60% efficiency, ultra-low emissions, and 40,000-hour stack life.

The Department is also working with industry to test and validate the PEM technology at the 1-kilowatt level and to transfer the technology to the Department of Defense. Further development in PEM fuel cells for both stationary and mobile applications is also underway. Development efforts include building applications and higher temperature operations for buildings cooling, heating, and power systems. Demonstrations are underway for PEM fuel cells in remote power applications, and work is being done to improve reformer technologies for making hydrogen from fossil fuels.


PEM Fuel Cell

Geothermal Systems. Geothermal power plants use the natural heat of the earth's interior to drive a turbine generator and produce electricity. Installed geothermal capacity in the U.S. today exceeds 2,800 megawatts. Today, electricity is produced from hydrothermal resources (reservoirs of steam or hot water) in the western U.S. In the future, hot dry rocks, which are far more abundant, could contribute to the nation's portfolio of geothermal resources.

The mission of the program is to work in partnership with U.S. industry to establish geothermal energy as an economically competitive contributor to the nation's supply portfolio. The goals are to double the number of geothermal producing states by 2006, reduce the costs to $0.03-$0.05 per kilowatt-hour by 2007, and reach 7 million homes by 2010. These goals will be accomplished by continuing efforts for small-scale field verifications for opening new geothermal fields, development of enhanced geothermal systems on a cost-shared basis with industry, and testing of high-speed data links for advanced drilling systems. Activities in field development, exploration, and drilling technologies will be jointly undertaken with related efforts in oil and gas and carbon sequestration.

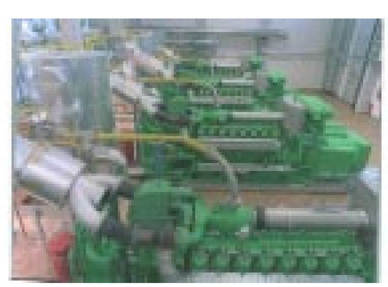
Hybrid Systems. Hybrid systems consist of two or more types of distributed energy technologies. The separate units are integrated into packaged hybrid systems that can provide an improved array of energy services to customers. Several different concepts for hybrid distributed energy systems are currently being developed. CHP systems are examples of hybrid distributed energy systems that combine power, heating, cooling, and humidity control systems into packaged units for commercial, industrial, and district energy users.

One prominent hybrid concept involves the integration of fuel cells and gas turbines. This type of hybrid system has potentially higher efficiencies and lower emissions than the individual systems have separately. Efforts to develop the next generation turbine systems include engine systems for integration with fuel cells to produce all hybrid configurations. Fuel cell/turbine hybrid systems use rejected thermal energy from the high temperature fuel cells to drive a combustion turbine. Once developed, these ultra-high efficiency systems (30 megawatts and larger) can potentially serve industrial and large commercial power markets. The goal is to introduce commercially near-term fuel cell/gas turbine hybrids capable of 70% efficiency by 2010. By 2015, the goal is for industry to demonstrate multi-megawatt fuel cell/turbine hybrid systems using solid state fuel cells developed under the Solid State Energy Conversion Alliance initiative.

SOFC–Turbine Hybrid

The conceptual fuel cell/turbine power plant system configures the high-temperature MCFC or SOFC with a combustion turbine and metallic recuperator. Synergistic effects of combining fuel cells and combustion turbines lead to electrical conversion efficiencies of more than 70 percent. Unit sizes can range from less than 1 megawatt up to 200 megawatts. A prototype unit is now completing acceptance testing. Research and development in combustion and modeling to support the hybrid systems activities is currently being conducted.

Another category of hybrid systems involves the use of fossil and renewable power systems in combination. Fossil/renewable hybrid systems offer advantages to both types of systems including lower emissions for fossil power production and continuous power for those times when wind and solar resources are not available. These systems work by coupling fossil generation units with wind or concentrating solar power systems and possibly battery storage



Natural Gas Engine

technologies. These systems can be packaged as stand alone units for remote power operations. When the sun is shining and/or the wind is blowing, the energy generated is either provided to users or is used to charge a battery storage system. New efforts are being explored in this area.

Natural Gas Engines. The reciprocating engine is a widespread and well-known technology. Spark ignition gas-fired units, the focus here, typically use natural gas or propane. Capacities are typically 0.5-5 megawatts but range up to 10 megawatts. Reciprocating engines offer low capital cost, easy start-up, proven reliability, good load-following characteristics, and heat recovery potential. The incorporation of exhaust catalysts and better combustion design and control has significantly reduced pollutant emissions over the past several years.

Reciprocating, or piston-driven, engines are the fastest selling distributed generation technology in the world today. Existing engines achieve efficiencies in the range of 30 percent to over 40 percent. Further efficiency improvements are possible, as are improvements in environmental performance. Examples include thermal capture concepts to convert waste heat into power and combustion modification techniques such as enabling a variable compression ratio.

A key effort is to produce next generation of natural gas engines for distributed power applications. Performance targets for advanced natural gas engines are: 1) increase fuel-to-electricity conversion efficiencies (low heating value) by at least 20 percent compared to existing models in all size ranges; 2) reduce emissions of $NO_{x,}$ hydrocarbons, air toxics, and greenhouse gases by at least 20 percent compared to existing models in all size ranges; 3) achieve average time between maintenance intervals equal to or better than existing models (15,000 to 24,000 between overhauls of the cylinder head and 40,000 hours between engine overhauls); 4) system costs equal to or better than competitive alternatives for market applications; and 5) capability to use multiple fuels including natural gas, diesel, hydrogen, landfill gas, propane, and biomass derived gases and liquids.

Photovoltaic Systems. Photovoltaic systems use semiconductor-based cells to directly convert sunlight to electricity. Cells use both thin film and crystalline silicon materials. The greater the intensity of the light, the more power that is generated. Photovoltaic systems can be used to generate electricity on almost any scale, depending on how many modules are connected together. Current average costs are about $4.25 per watt and annual sales were about 201 megawatts worldwide in 1999. Costs have been reduced by 50 percent since 1991 and sales have been increasing steadily, particularly in remote power operations.

The goals by 2004 are to reduce manufacturing costs of modules to $1.50 per watt (equivalent to $0.15 per kilowatt-hour); facilitate industry growth of 25 percent per year to reach 1 gigawatt of cumulative sales; and increase the efficiency of thin film modules from 7 to 12 percent. To achieve these goals, efforts in technology development, advanced materials and devices, and fundamental research will continue. Work will proceed on the industry roadmap, a stronger university research program will be established to push for breakthroughs in lower cost materials, and greater emphasis will be placed on industry development of low-cost thin film (double the conversion efficiency to 20 percent) and on high efficiency, multi-junction concentrator cells.


Wind Turbines

Wind Energy Systems. Wind turbines convert the kinetic energy of the wind into electricity. Most wind machines use 2-3 propeller-like blades mounted on a rotor connecting to an electric generator that is typically 0.5-1 megawatt in capacity. Larger sizes have been tested and are now entering the commercial market. Wind energy systems are modular and can be clustered in areas with good wind resources to form wind farms of 50-100 megawatts or larger. There are approximately 16,000 wind energy systems in operation in the U.S. today.

Efforts in wind energy focus on helping U.S. industry complete advanced research and development and overcome barriers to wind energy use. The goals are to reduce the costs of wind energy to $0.025 per kilowatt-hour by 2002; achieve 100 megawatts of distributed, off-grid applications by 2005; and to reach 10,000 megawatts of installed wind capacity by 2010. These goals will be accomplished by continued efforts in regional field verification, development and testing of the “next generation” of wind turbines, and partnerships for the fabrication and testing of innovative technologies with industrial partners.

B. TECHNOLOGY BASE DEVELOPMENT

Combustion Systems for Power Generation. Combustion is the chemical conversion process for making thermal energy from fuels. Increasing the energy efficiency of combustion processes for power systems can lower fuel consumption, energy costs, and emissions. One of the most pressing issues for distributed energy systems is meeting increasingly stringent local environmental requirements, particularly when siting facilities in ozone non-attainment areas. Advanced combustion processes for power generation can lower emissions substantially and thereby expand the range of potential installations in manufacturing and industrial processing plants, commercial buildings, government facilities, hospital complexes, college campuses, public housing, municipalities, and power parks. One of the major targets involves reductions in NO_x emissions, an ozone precursor. Efforts are underway in the advanced industrial combustion systems program to develop new technologies that better integrate burners and boilers to maximize heat transfer and lower NO_x emissions. The potential for similar integration of advanced combustion technologies in distributed energy generation systems needs to be explored for electricity and combined heat and power applications.

Materials & Manufacturing. Engineered ceramics such as continuous fiber ceramic composites (CFCC) show tremendous promise for enabling higher temperature operations for combustion systems in engines, turbines, and furnaces. Higher temperature operations can mean higher efficiency and lower emissions. Although many ceramics perform well at considerably higher temperatures than conventional metal alloys, they are generally brittle and as a result can exhibit catastrophic failures in service. CFCCs offer all of the advantages of ceramics – resistance to heat, corrosion, erosion, and chemical activity – while adding toughness and thermal shock resistance. Efforts are underway and/or planned for demonstrating CFCC components such as combustion liners and turbine tip shrouds for gas turbines.

Advanced Materials

Materials and manufacturing efforts are also needed for developing advanced solid oxide fuel cells in support of the Solid State Energy Conversion Alliance. Major areas of needed development involve: 1) cost-effective fabrication techniques for high performance fuel cell stacks; 2) new interconnect alloys from fundamental understanding of oxidation kinetics and oxide conductivity; and 3) fabrication techniques such as multi-cell stack extrusion processes, one step firing processes, and other new techniques for making ceramics reliably and with a minimum number of defects.

Fuel Processing. Fuel processors are an important enabling technology for the development of distributed energy technologies. One of the most important R&D needs in fuel processors is the development of a compact fuel processor for diesel and logistics fuels. Development efforts need to address novel fuel conversion processes, e.g., advanced oxygen sources for partial oxidation and micro-channels to enhance heat transfer; fuel pre-processing systems to remove troublesome impurities before they are charged to the fuel processor; anode catalysts that are resistant to sulfur and carbon; and advanced balance of plant systems.

Another important R&D need involves the development of low-cost, compact fuel processors for natural gas, propane, and gasoline through: thermal integration, miniaturization of equipment for 5 kW, simplified designs for PEM fuel cells, multi-fuel R&D, integrated fabrication development, and lowering components costs.

An additional R&D need in fuel processing for fuel cells involves the development of internal reforming technologies which include: steam reforming and POX, lab tests of internal reforming systems, electrochemical and thermodynamic models of fundamental processes, multi-fuel tolerant core modules, graded anode technology, and advanced fuel mixing concepts to facilitate heat transfer and management.

Hydrogen Energy Systems. Hydrogen energy has the potential to replace fossil fuels in every sector of the economy. Eventually, the clean and sustainable production of hydrogen will require the use of renewable resources such as solar, wind, and hydropower. Currently, hydrogen is produced primarily from the steam reforming of natural gas. Other hydrogen production methods include electrolysis and photoconversion. Hydrogen is used in fuel cells and in the future could be widely used to fuel turbines and engines. The lack of low cost and efficient hydrogen production, storage, and delivery technologies is one of the major factors that limits the expanded use of hydrogen in distributed energy applications. The Hydrogen Program conducts core R&D in the development of hydrogen energy concepts, components, and subsystems. This includes support for basic and applied research and materials development. Technology validation efforts include systems integration and prototype development in the production of hydrogen using renewable and other approaches, hydrogen infrastructure, and remote and village power.

Power Electronics. A low-cost, durable, and reliable electronic interface is necessary for the proper interconnection of distributed energy resources with both utility and customer systems. Some of the important features of the development effort in power electronics includes alignment with manufacturing requirements, development of an open architecture for common module hardware and software toolkits, identification of common denominators from developers across applications, assessment of packaging requirements, development of uniform codes and standards across industries, development of communication systems and protocols, and development of diagnostics and predictive controls. The following reliability and thermal management needs also should be addressed: the development of better, faster, smaller, and cheaper components; improved higher temperature capabilities for connections, solder, circuit boards, and substrate; improved switching characteristics with lower losses and higher temperature; and improved heat sink integrated thermal management.

Sensors and Controls. Worldwide markets for sensing technologies and for process controls are $15 billion and $26 billion annually. The U.S. is the largest market for and manufacturer of these technologies. Advanced sensors are needed for distributed energy systems development and integration into the power system, buildings, and manufacturing processes. These sensors will measure various performance parameters such as temperature, pressure, efficiency, emissions, costs, and other factors and include communications systems for remote monitoring and control. Further efforts are needed to develop sensors that can operate under high temperature and pressure conditions and that are capable of providing real-time data for system optimization. A new generation of adaptive control systems is being developed to enable remote dispatch and controls, enhance the reliability of the grid, and facilitate the operation of smart buildings.

C. Systems Reliability, Architecture and Integration

The Department's Energy Grid Reliability Initiative will assure that distributed energy technologies support electric grid reliability and that gas-fired distributed energy equipment integrates into both the electric and natural gas systems for maximum efficiency, security, and reliability.

Storage. Cost effective and efficient energy storage devices are critical components in the deployment of reliable distributed energy resources. Coupled with renewable and natural gas generation systems, power conditioning equipment, and remote power systems, energy storage devices can be used to provide safe and reliable power for on- and off-grid applications. Energy storage can also be used to support peak shaving strategies and can be operated for both grid support and power quality. Lead-acid battery storage systems are in commercial use today. Other options include compressed air storage, superconducting magnetic energy storage systems, flywheels, ultra capacitors, and other advanced battery technologies. Development efforts are currently focusing on the evaluation of power quality benefits from demonstration sites in the southeast and testing of an advanced 400 kWh zinc-bromide battery storage device.

Battery Storage

Grid Interconnection. Interconnection hardware, software, and power electronics for distributed energy resources will be developed to ensure their safe and efficient operation in the nation's power grid. Advanced sensors and controls are essential for optimizing system operations and diagnosing problems on-site or from remote locations. Distributed energy resources use sensors and control systems for measuring power output, revenue metering, conveying real-time price signals, data acquisition, and communications. Remote dispatch of distributed energy resources can be a cost effective means for aggregating dispersed power supplies, or demand management capabilities, into larger resources to support grid operations. Efforts are underway to develop interconnection systems that are cost effective for smaller scale power generation devices.

Modeling and Simulation. Modeling and simulation tools are needed to design distributed energy systems and to ensure optimized performance. Development work is needed in a number of areas including data collection, analysis, calibration, and verification and validation. Measurement and data acquisition systems that extract information from distributed power units and calibrate operating systems for optimized performance are needed. Lower cost communications hardware and software are needed to ensure that models and simulation tools are capable of handling high-speed data exchange under dynamic circumstances. Autonomous and distributed "logic" that can carry out system decision making to ensure safe and reliable interconnection of distributed energy systems need to be developed. Models and decision tools are needed to assist users in selecting the optimum mix of energy supply and demand management options.

Power Parks, MiniGrids and District Energy. Power parks combine small distributed technologies using a distribution or "mini" grid. They can involve innovative applications of the grid including a premium grid and/or a DC grid. Customers in a power park are generally in close proximity to one other and to the primary energy resources in order to make productive use of waste heat for hot water, steam, and cooling purposes. Power parks and district energy systems may involve industrial parks, manufacturing plants, housing developments, commercial buildings, office complexes, hospitals, or school campuses. Often, a thermal loop may be used to provide district heating and cooling, as well as process heating. The concept of the "virtual" power park involves the use of sophisticated control technology to manage multiple distributed energy facilities and demand management approaches installed throughout a locality or region.

Superconducting Cable

Superconducting Materials for Electric Systems. High temperature superconducting materials were first discovered in 1986 and use an obscure group of ceramic oxide compounds. Applications for superconducting materials in motors, generators, cables, inductors/transformers, and energy storage devices that were only dreamed of in 1986 are now within reach. Wire made from high temperature superconducting materials has better efficiency and lower losses than wire made from copper or aluminum. Transformers that use superconducting coils will be more efficient, non-flammable, and have less environmental impact than conventional transformers. Inductive current controllers made from high temperature superconducting materials will provide increased power system stability by allowing equipment to safely operate at higher voltage and current capacities than is now possible. These systems can be used in distributed energy resource applications in advanced electric motors, electricity storage devices, and in "mini" grids in power parks. Efforts are planned to develop superconducting materials and a variety of equipment applications for electric systems. These include improving the current density of wires and coils, and testing cables, transformers, and motors.

Transmission and Distribution (T&D) Systems. The operation of the nation's power grid links over 10,000 power plants and nearly 3,500 utilities, under the supervision of 150 control areas and 22 security coordinators in 3 functionally and physically independent regional interconnections. Deployment of distributed energy resources on a large scale will require integration into this complex electric distribution system. The Department's Energy Grid Reliability Initiative will assure that distributed energy technologies support electric grid reliability and that gas-fired distributed generation integrates into both the electric and natural gas systems for maximum efficiency, security, and reliability. The initiative is also concerned with protecting the electricity and gas delivery systems from deliberate attack. T&D system research and development also includes: accelerated development of satellite-synchronized measurement systems, advanced power electronics technologies, real-time system monitoring and control, and analyses to assess the interaction of competitive markets and electric system reliability.

D. Systems Implementation and Outreach – Regulatory and Institutional Barriers

A major step in systems implementation is the identification of the most productive deployment pathways. The purpose of this area of activity is to accelerate the commercialization of distributed energy resources. Existing and planned activities focus on addressing the regulatory and institutional barriers that inhibit the expanded use of distributed energy resources. Many of the these barriers were recently documented in the report *Making Connections – Case Studies of Interconnection Barriers and Their Impact on Distributed Power Projects*, published by the National Renewable Energy Laboratory in May 2000. One of the major activities related to removing barriers involves support for the industry-driven vision and roadmap process in support of the Department's *CHP Challenge,* which calls for doubling the amount of installed CHP capacity in the U.S. by 2010. Activities in support of the *CHP Challenge* include outreach to policy officials to make them aware of the benefits of CHP as well as the challenges of siting, permitting, and interconnection barriers.

Building Codes and Standards. Commercial, government, and residential buildings are important targets for distributed energy systems. Building codes, energy codes for buildings, and indoor-air quality standards need to reflect the needs and operating parameters of distributed energy systems. Effort is needed to work with building codes and standards officials to determine the impact of existing codes and standards on the potential use of distributed energy systems in buildings. Effort is also needed to identify issues and initiate actions to revise building codes and standards as necessary to accommodate the needs of distributed energy systems.

Environmental Siting and Permitting. The U.S. Environmental Protection Agency (EPA) is considering the use of output-based emission standards for siting and permitting power plants. Consideration is also being given to New Source Review policies and procedures for siting and permitting new power plants. Another possibility involves pre-certification of certain types of distributed energy systems to ease the siting and permitting process for developers and users. All of these activities affect the deployment of distributed energy systems. Further coordination efforts are needed to ensure that environmental siting and permitting policies of federal and state governments are implemented properly and address the needs of distributed energy systems. The Department is working with EPA and state and regional air quality boards to provide information on the costs and benefits of distributed energy systems. Examples of this coordination effort include the recently announced EPA-DOE Energy Star Award for CHP facilities.

Federal Energy Management Program. President Clinton's recent Executive Order 13123 on federal energy use is designed, in part, to promote the use of distributed energy resources in the federal government's 500,000 buildings, where about $3 billion is spent annually on energy services. The Executive Order directs federal agencies to increase the use of distributed energy resources, both renewable and natural gas-fired, in order to cut pollution and greenhouse gas emissions and increase source energy efficiency. The Federal Energy Management Program (FEMP) has the lead in the Department for implementation of the Executive Order.

International PCAST. The President's Council of Advisors on Science and Technology (PCAST) recently completed a study on international cooperation in energy research, development, demonstration, and deployment. The study found that the worldwide application of DER systems would offer substantial economic, energy, and environmental benefits. The Department is working on strategies to implement the recommendations contained in the PCAST report.

Standardized Interconnection Protocols. Each utility has its own set of interconnection requirements that are designed to protect the safety of utility personnel and the quality of power injected into the distribution system. Continued work with the Institute of Electrical and Electronic Engineers (IEEE) is needed in order to develop standardized interconnection procedures for all utilities to consider and use. Standardization would reduce barriers to the deployment of DER systems and make interconnection costs more certain for distributed energy developers and users.

State Initiatives. Collaborative applied research, development, and field testing with the states is being pursued in the area of distributed energy resources including CHP, fuel cells, and microturbines. This includes the provision of financial assistance for studies of CHP feasibility and the development of computer decision tools for the evaluation of distributed energy systems.

Tax Provisions. Tax treatment of distributed energy systems is not currently handled on a consistent basis compared to central station power plants. Revisions to tax policies can be an important financial incentive for the expanded development and deployment of distributed energy systems. The Treasury Department is considering tax credits and revised depreciation schedules for CHP systems. Further effort is needed to work with the Treasury Department and others to ensure that changes to the tax code for distributed energy systems are designed properly with maximum benefit for developers and users and minimum impact on federal revenues. The Department is working with the Treasury Department and others in the analysis of tax provisions for distributed energy systems.

Utility Restructuring. As of September 2000, twenty-four states and the District of Columbia have enacted comprehensive electricity restructuring legislation or regulatory orders. More than one dozen federal electricity bills have been introduced in the 106th Congress. The Administration has developed a Comprehensive Electricity Restructuring Plan. These policy developments have tremendous effects on the development and deployment of distributed energy systems. Further efforts are needed to assist state restructuring officials in the development of policies and proposals that properly address distributed energy resources issues. This involves support for workshops, seminars, and studies.

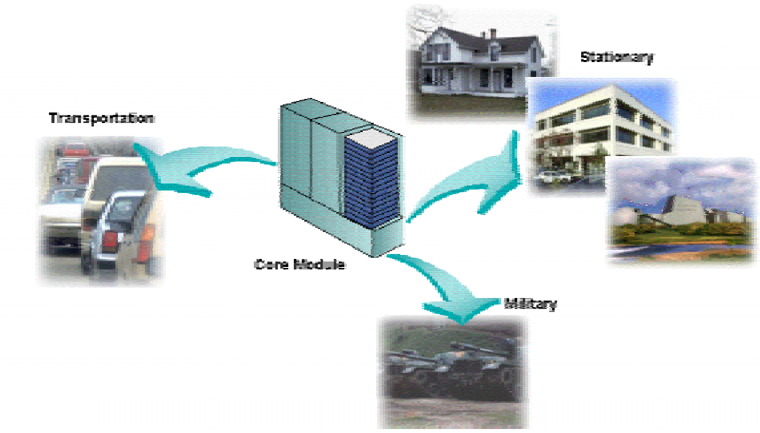
F. Initiatives

Plans for several future initiatives to achieve the vision, mission, and goals of the program are under consideration. Distributed energy resources occupy niche markets today; expanded development is constrained by the lack of standardized systems, products, and services, uneven integration of those products and services into normal business operations, and regulatory and institutional barriers. In addition, extensive research and development opportunities exist for new products and services that will potentially achieve the goals for clean, affordable, and reliable energy generation.

Biofuel Flexibility. The purpose of this initiative is to develop advanced combustion systems and materials for the use of biobased fuels (liquids and gases) in turbines, reciprocating engines, and fuel cells. New combustion technologies and materials are needed to address fouling and corrosion problems caused by biobased fuels with relatively high moisture content and relatively low BTU values. The economics of processing biobased fuels into liquids and gases is a major issue, as is whether or not this processing should be done on-site or in centralized locations. This initiative will be coordinated with existing and planned efforts in biobased energy and bioproducts.

Fossil-Renewable Hybrids. The purpose of this initiative is to develop new control systems, subsystems, and components for coupling intermittent renewable power systems (e.g., solar and wind) with advanced fossil energy generation equipment (e.g., fuel cells, turbines, microturbines, and reciprocating engines). Efforts will be undertaken to develop and test packaged hybrids under operating conditions in several regions of the country. The first phase would involve the packaging of off-the-shelf equipment to identify areas where further development is needed. Data will be collected on case studies of existing renewable-fossil hybrids in remote power applications.

Solid State Energy Conversion Alliance (SECA). In 2000, SECA was created to bring industry, national labs and universities together to realize the full potential of the fuel cell technology. The vision of this alliance is to develop mass produced ceramic fuel cells for low-cost power. Through SECA, solid state fuel cells will be deployed in a wide variety of stationary applications for distributed power as well in the transportation sector (initially for auxiliary power units and ultimately for vehicle propulsion). Many potential military uses exist in this technology, from powering ships to generating auxiliary power units in tanks and trucks. By 2003-05, SECA expects to field a 5-kilowatt market entry solid state fuel cell using solid state composition for the stationary, military, and auxiliary power unit markets. By 2015, SECA expects to develop advanced fabrication techniques and low and intermediate temperature materials to achieve 80% efficiency, near-zero emissions, 40,000-hour stack life, and capital cost of $400 per kilowatt (<$90 per kilowatt stack) for mature, long-term power plants.



SECA Vision: A Core Module for Multiple Applications

Systems Architecture. The purpose of this initiative is to develop equipment, devices, and software to ensure that distributed energy systems can interconnect with utilities and customer operations in factories, commercial and government buildings, office and hospital complexes, industrial parks, campuses, and municipalities. The goal is to develop "plug&play" systems that can be easily interconnected, operated, and maintained. These automation and integration systems would involve telecommunications equipment, including Internet-based systems, for remote data acquisition, monitoring, troubleshooting, and dispatch. This initiative will be coordinated with existing and planned efforts in energy grid reliability, T&D systems, energy storage, industrial sensors and controls, and buildings cooling, heating, and power technologies.

Systems Integration, Testing, and Case Studies. The purpose of this initiative is to develop and disseminate information to key decision makers on the costs and benefits of distributed energy resources. A key aspect of this initiative is the application of distributed energy resources in power parks as a way to organize demonstration projects with respect to instrumentation, data acquisition, monitoring, and control equipment in a variety of utility, commercial, institutional, municipal, and residential applications. These efforts would involve a high degree of cost sharing with industrial partners. Another aspect of the effort would involve documenting regulatory and institutional barriers and the steps taken to overcome them. These types of case studies would investigate utility interconnection issues and policies, environmental siting and permitting, and safety and building code issues. This initiative would be closely coordinated with existing and planned efforts in utility restructuring, standardized interconnection protocols, electricity reliability regulations, and the *CHP Challenge*.

Zero Energy Buildings. The Zero Energy Buildings vision is to integrate solar energy technologies with energy efficient construction techniques to help create a new generation of cost-effective buildings that have a zero net annual need for fossil fuel energy. The Solar Buildings Program has recently adopted this vision as its long-term goal, and has begun to coordinate its activities with the Office of Building Technology, State and Community Programs (BTS) as well as with the renewable power generation programs within the Office of Power Technologies (OPT). It is the combined output from these programs that offers the potential for a package of solar technologies that can economically provide all the energy needed by a building. In a true sense, Zero Energy Buildings is a crosscutting R&D effort to place distributed energy resources systems in buildings.

G. Multi-Year Outlook

This program plan calls for activities in four main areas toward the development and demonstration of distributed energy resources over the next five fiscal years. These areas are:

- Systems Architecture and Integration
- Technology Development
- Technology Base Development
- Systems Implementation and Outreach

Tables 2 and 3 provide a multi-year outlook and a summary of current year funding for DOE investments in these areas.

Table 2. Multi-Year Outlook

DER Program Area	Appropriated FY 2000	Requested FY 2001	Outyear Targets
Systems Architecture and Integration	$37.3 M	$48.0 M	• Systems design and testing • Documentation of operational benefits • Modeling and simulation
Technology Development	$225.0M	$254.0M	• Lowered costs and improved efficiency • Systems integration • Hybrids
Technology Base Development	$11.0 M	$5.5 M	• Cost reductions • Manufacturing costs and processes • Technology integration
Systems Implementation and Outreach	$5.6 M	$6.5 M	• Reduced institutional and regulatory barriers • Expanded industry partnerships • Vision and roadmap implementation • Case studies of best practices

TABLE 3. SUMMARY OF CURRENT YEAR FUNDING

PROGRAM	FY 2000 FUNDING ($ MILLIONS)
Systems Architecture and Integration	
Transmission Reliability	2.5
Storage	3.4
Superconductivity	31.4
Total	**37.3**
Technology Development	
Photovoltaics*	65.9
Concentrating Solar	15.2
Solar Buildings	2.0
Wind*	32.6
Geothermal*	23.6
Turbine Systems (FE)	3.0
Industrial Power (advanced industrial turbines, natural gas engines, microturbines)	24.3
Absorption Chillers	6.3
Desiccants	4.0
Fuel Cells (EE)	3.6
Fuel Cells (FE)	44.5
Total	**225.0**
Technology Base	
Advanced Engine Materials	5.5
Advanced Turbine Engine Technologies (Materials, Combustion, Aero-Heat Transfer) (FE)	5.5
Total	11.0
Systems Implementation and Outreach	
Combined Heat and Power	1.0
District Energy	0.1
Restructuring	1.0
DER Integration	3.5
Total	**5.6**

***Contains some funding for central station renewable power development**

6. PROGRAM BENEFITS

The benefits provided by this program and distributed energy resources could be significant for customers, energy suppliers, and the nation as a whole. These benefits are summarized below.

CUSTOMER BENEFITS

- Ensures reliability of energy supply, increasingly critical to business and industry in general and essential where interruption of service is unacceptable economically or when health and safety is impacted;
- Provides the power quality needed in industrial applications that are dependent upon sensitive electronic instrumentation and controls;
- Offers efficiency gains for on-site applications by avoiding line losses and using both electricity and heat produced in power generation for processes or heating and air conditioning;
- Enables savings on electricity rates by self-generating during high-cost peak power periods and adopting relatively low-cost interruptible power rates;
- Provides a stand alone power option for areas where transmission and distribution infrastructure does not exist or is too expensive to build;
- Allows power to be delivered in environmentally sensitive and pristine areas by having characteristically high efficiency and near zero pollutant emissions;
- Affords customers a choice in satisfying their particular energy needs; and
- Provides siting flexibility by virtue of their small size, superior environmental performance, and fuel flexibility.

SUPPLIER BENEFITS

- Limits capital exposure and risk because of the size, siting flexibility, and rapid installation time afforded by small, modularly constructed, environmentally friendly, and fuel flexible systems;
- Avoids unnecessary capital expenditure by closely matching capacity increases to demand growth;
- Avoids major investment in transmission and distribution system upgrades by siting new generation near the customer;
- Offers a relatively low-cost entry point into a competitive market; and
- Opens markets in remote areas without transmission and distribution systems and in areas without power as a result of environmental constraints.

NATIONAL BENEFITS

- Reduces greenhouse gas emissions through efficiency gains and potential renewable energy use;
- Responds to increasing energy demands and pollutant emission concerns while providing low-cost, reliable energy essential to maintaining competitiveness in the world market;
- Positions the United States to export distributed generation technologies in a rapidly growing world energy market, the largest portion of which is devoid of a transmission and distribution grid;
- Establishes a new industry worth billions of dollars in sales and hundreds of thousands of jobs; and
- Enhances productivity through improved reliability and quality of power delivered, valued at billions of dollars per year.

7. GLOSSARY OF TERMS

Ancillary Services – A number of functions, such as spinning reserves and reactive power, which are necessary to support the reliable and efficient operations of the transmission system.

Bulk-Power System – The portion of the Nation's electric power system that encompasses central station generation plants, system controls, and the high voltage power transmission system.

Control Area – An electric system or systems, bounded by interconnection metering and telemetry, that is capable of controlling generation to maintain interchange schedules with other control areas and contributing to the frequency regulation of the interconnection.

Cooling, Heating, and Power (CHP) – Also known as combined heat and power and cogeneration, CHP is the sequential production of electricity and useful thermal energy such as steam, hot and chilled water, refrigeration, and humidity control.

Demand Management – Technologies, tools, and techniques that affect customer use of electricity or natural gas, both the timing (sometimes referred to as load management) and the amount (sometimes referred to as energy efficiency).

Distributed Energy Resources – Supply- and/or demand-side devices that provide electricity, thermal, and/or mechanical energy. These resources can be located on-site or nearby to the users. They can be used to meet baseload power, peaking power, backup power, remote power, power quality, and cooling, heating, and power needs.

Distributed Generation – A subset of distributed energy resources and distributed power. Energy supply devices ("prime movers") for providing electricity, thermal, and/or mechanical energy to users from on-site or nearby locations.

Distributed Power – A subset of distributed energy resources. Distributed generation devices and the storage and interconnection equipment needed to interconnect with customers and/or the utility grid.

Distribution System – The portion of an electric system that delivers electricity from the bulk-power system to retail customers, consisting primarily of substations, low voltage feeder lines, and transformers.

Electric Power System – An interconnected combination of generation, transmission, and distribution components that make up an electric utility, an electric utility and one or more independent power producers, or a group of utilities and one or more independent power producers.

Electric Utility – Corporation, agency, person, authority, or legal entity that owns or operates facilities for the generation, transmission, distribution, or sale of electricity primarily for use by the public and is defined as a utility under the statutes and rules by which it is regulated. Investors, government agencies, or members of a cooperative can own an electric utility.

Energy Services Company (ESCO) – A commercial enterprise that sells energy, energy equipment, energy efficiency audits, engineering designs, on-site generation, and related services to end-use customers in the residential, commercial, and industrial sectors.

Grid – The system of interconnected power lines, switchgear, transformers, and generators that is managed so that the generators are dispatched as needed to meet the requirements of customers connected to the grid at various points.

Independent System Operator – This refers to the entity that is responsible for the neutral operation of the bulk-power system in a particular geographic area. The primary responsibility is to maintain the generation-load balance of the system in real-time. The independent system operator performs these functions by monitoring and controlling the transmission system for a given region and some generating units to ensure that the energy in the system is sufficient to meet load.

Interconnection – When used as a noun (capitalized "I"), this term refers to any one of the major electric system networks in North America. When used as a verb, this term refers to the process (electro-mechanical, regulatory, procedural) of connecting electricity generation and storage devices to the user and/or the utility system. When used as an adjective, this term refers to various types of equipment like switchgear, synchronous generators, and electronic inverters.

Load Management – Technologies, tools, and/or techniques for changing the timing of electricity usage such as reducing peak demand, or increasing use during off-peak periods. Includes direct load control, interruptible rates, time-of-use rates, and real-time pricing measures.

Public Utility Commission (PUC) – The state regulatory authority that oversees the performance of regulated utilities that operate in that state.

Reliability – The degree of performance of the elements of the power system that results in electricity being delivered to customers within accepted standards and in the amount desired. The frequency, duration, and magnitude of disruptions on the power system can measure the reliability of the power system.

Retail Electricity Markets – The purchase and sale of electricity from utilities to end-users. The buyers in retail markets are normally residences, commercial and industrial firms, and agencies of government. The sellers are normally distribution utilities.

Transmission & Distribution – The group of interconnected power lines and associated equipment for the movement of electric power from the central station power plant to the points-of-delivery to customers, which are normally substations.

Wholesale Electricity Markets - The purchase and sale of electricity from producers to distributors. The buyers in wholesale markets are normally distribution utilities, power marketers, power brokers, and other power systems. Some of the very large industrial users purchase power directly from wholesale markets.

8. WEBSITE INFORMATION

Additional information on Distributed Energy Resources may be found at the following websites:

www.eren.doe.gov/der
www.netl.doe.gov
www.eren.doe.gov/power/transmission.html